Remote-sensing and spatial modelling of the relationship between environmental factors and vector-borne diseases

From research to operational activities for the development of monitoring and early warning systems

Thibault Catry, Claire Teillet, Emmanuel Roux, Benjamin Pillot, Vincent Herbreteau, Benjamin Pillot, Laurent Demagistri, Nadine Dessay

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Introduction

Vector-borne diseases are a burden on health systems and development in many tropical countries.

Many vector-borne diseases have emerged or re-emerged throughout the world, gaining new territories and affecting both animal and human health.

Persistence or emergence of these vector-borne diseases is conditioned by many climatic, environmental and demographic factors specific to each territory, at different scales.

Geomatics approaches have been used to better understand the epidemiological processes of vector-borne diseases and better predict their evolution in a rapidly changing world.

Interdisciplinary research

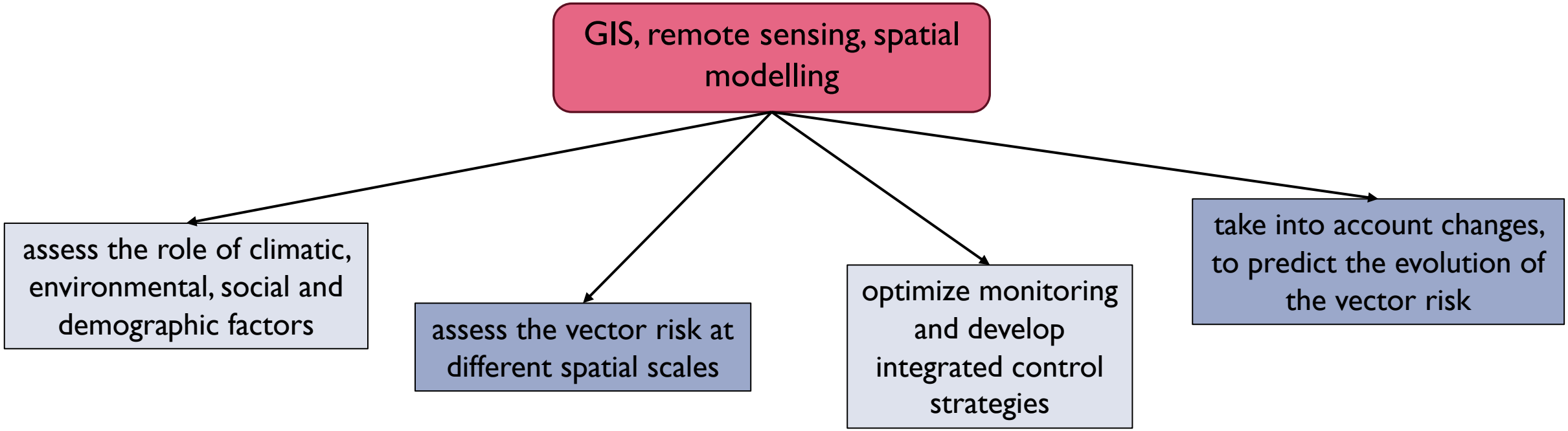
From research to prototyping of innovative and operational solutions in public health

Expertise in GIS, remote sensing, data and model sciences

Partnerships with entomologists, epidemiologists, veterinarians, public health actors, etc

"Territorialized" One Health approach for public and collective health

Introduction



How research activities based on remote sensing and spatial modelling can be integrated into operational activities dedicated to the development of monitoring and early warning systems in public health?

The example of Dengue Fever

Research activities in Remote sensing and spatial modelling

Relationship between urban factors and dengue cases/vectors dynamics in Brazil and French Guyana

Description of urban structure using textural information from remote sensing data

APUREZA, **DELICIOSA** and **ANISETTE** projects, funded by French Space Agency (CNES), TOSCA program 2017-2023

PROGYSAT Urban and Health axes

Remote sensing for health applications in urban context

Processes of exposure and transmission of vector-borne diseases like dengue fever at several scales

→ Multi scale analysis of urban structure and organization

→ Dynamics in space and time

FOTOTEX Method based on the analysis of textural information extracted from Earth observation data

https://framagit.org/espace-dev/fototex

https://pypi.org/project/fototex

remote sensing

MDPI

Article

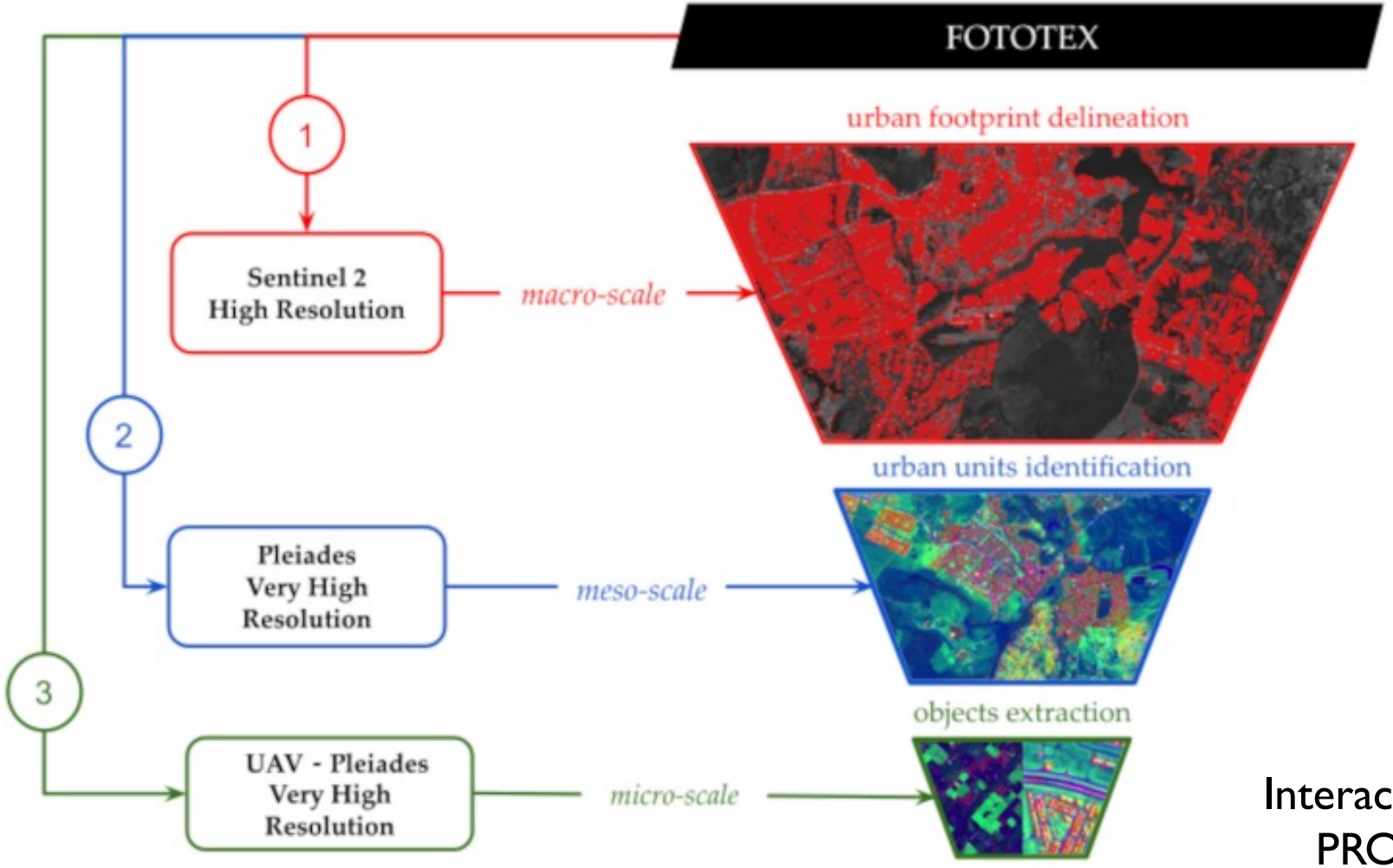
Fast Unsupervised Multi-Scale Characterization of Urban Landscapes Based on Earth Observation Data

Claire Teillet [1,*], Benjamin Pillot [1], Thibault Catry [1], Laurent Demagistri [1], Dominique Lyszczarz [2], Marc Lang [3], Pierre Couteron [4], Nicolas Barbier [4], Arsène Adou Kouassi [5,6], Quentin Gunther [7] and Nadine Dessay [1]

Description of urban structure using textural information from remote sensing data

Earth observation data can be used to **describe the urban space** and **delineate urban units**

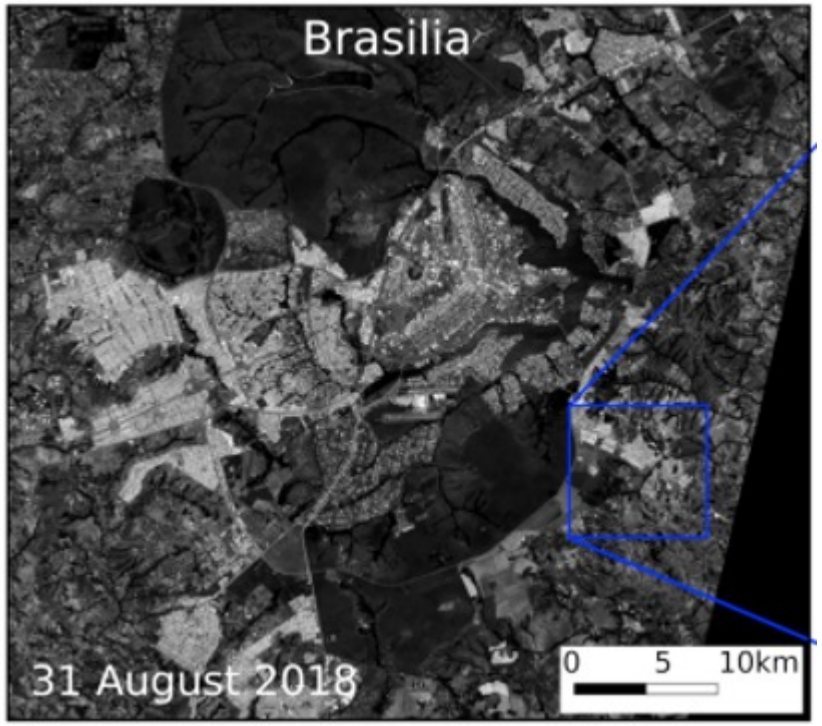
FOTOTEX for the multi scale analysis of urban structure and organization



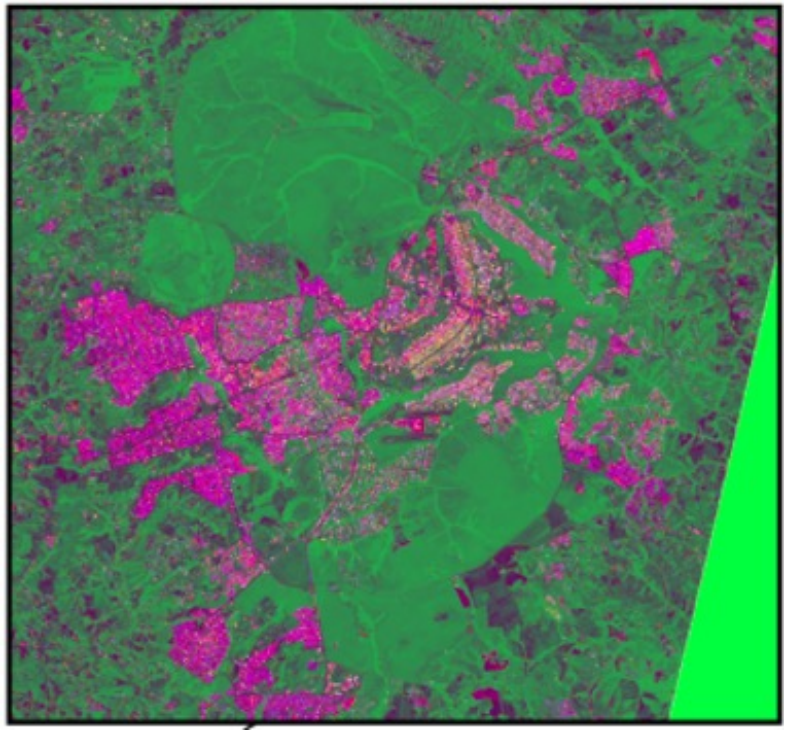
Teillet et al., 2021

Interactions with PROGYSAT « urban »

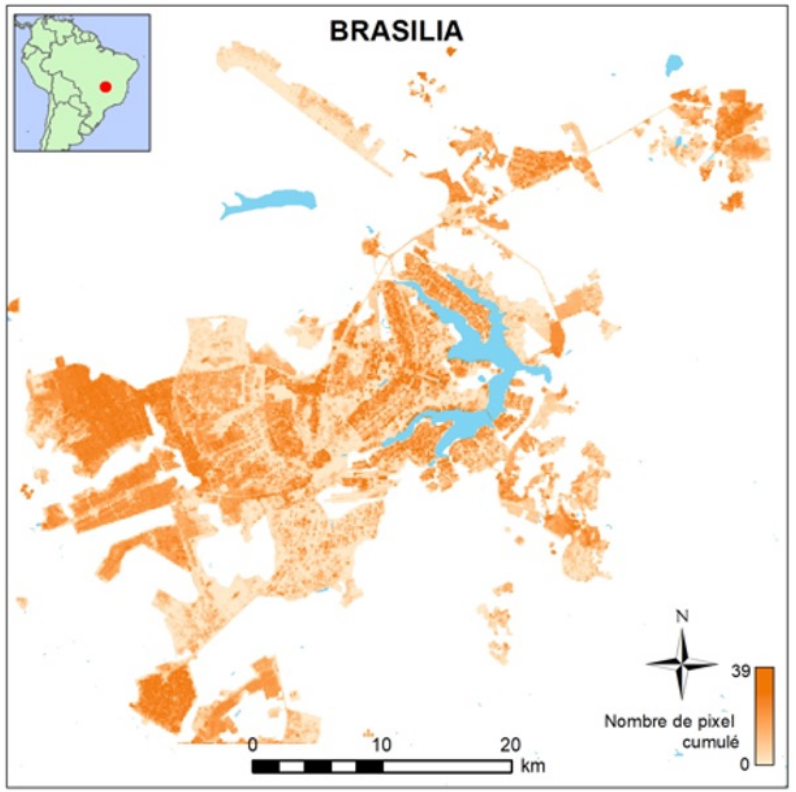
Description of urban structure using textural information from remote sensing data



MACRO-SCALE: Brasilia **Urban footprint** delineation

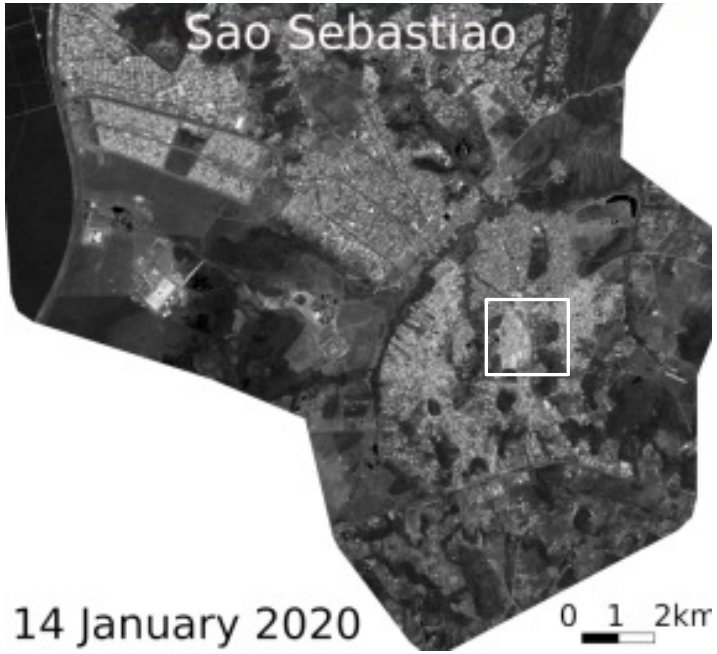


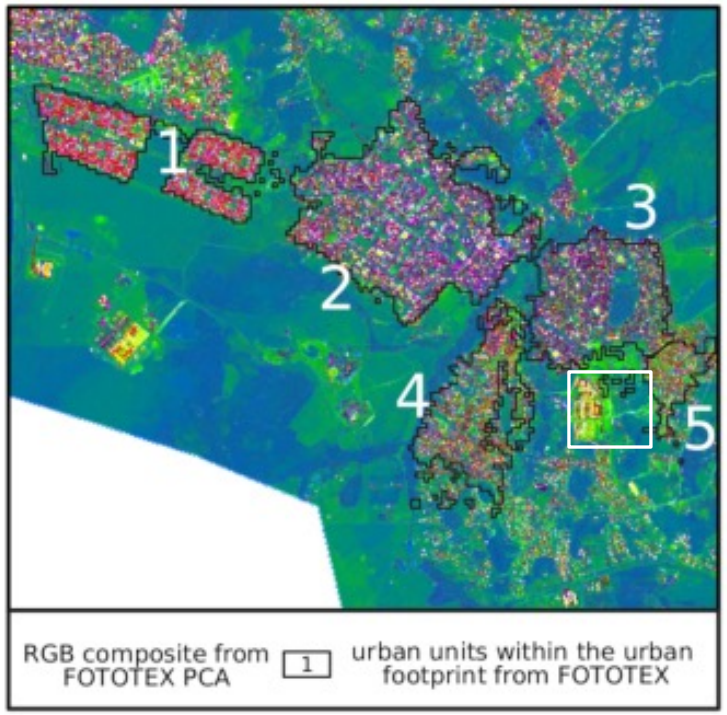
Application of FOTOTEX on Sentinel 2 (10 m)



Description of urban structure using textural information from remote sensing data

Application of **FOTOTEX** on Pléiades data (0.5 m) over Sao Sebastiao (Brasilia)



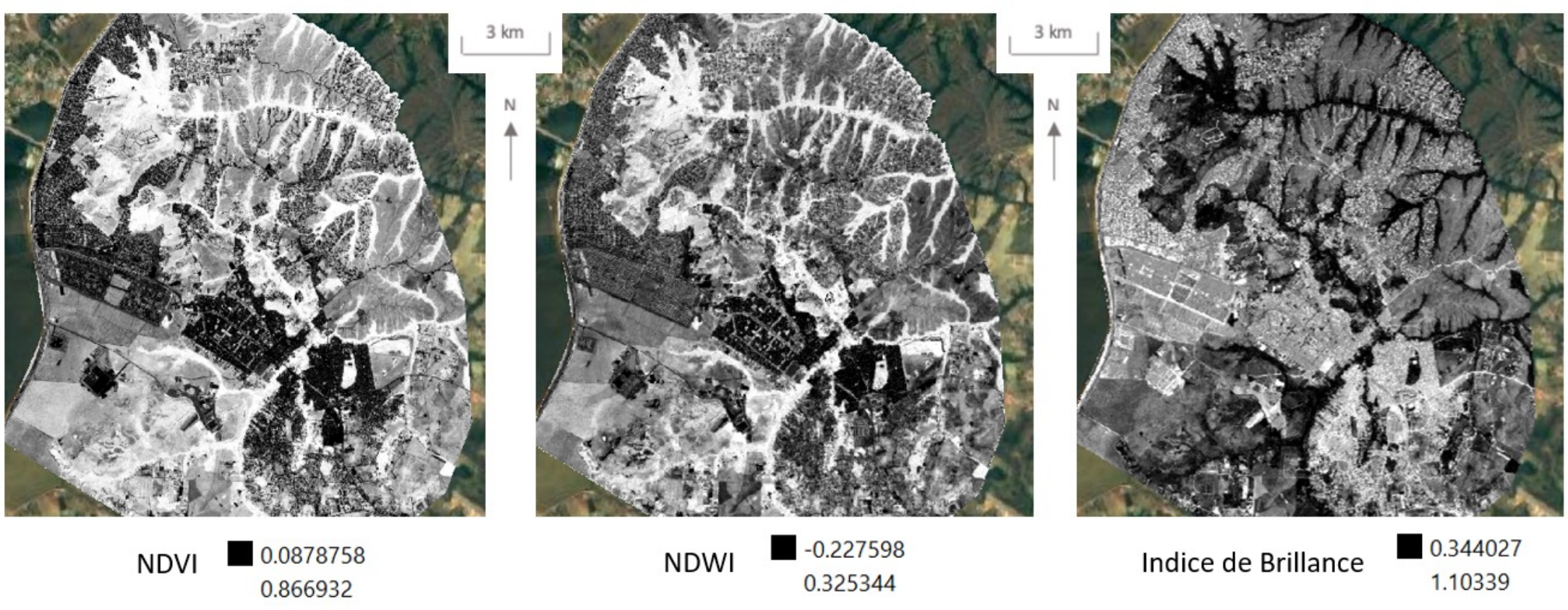


MESO-SCALE:
Urban Units
delineation

MICRO-SCALE:
Urban Objects
identification

Characterizing urban landscapes using remote sensing data

Earth observation data can be used to produce **environmental variables** on urban areas

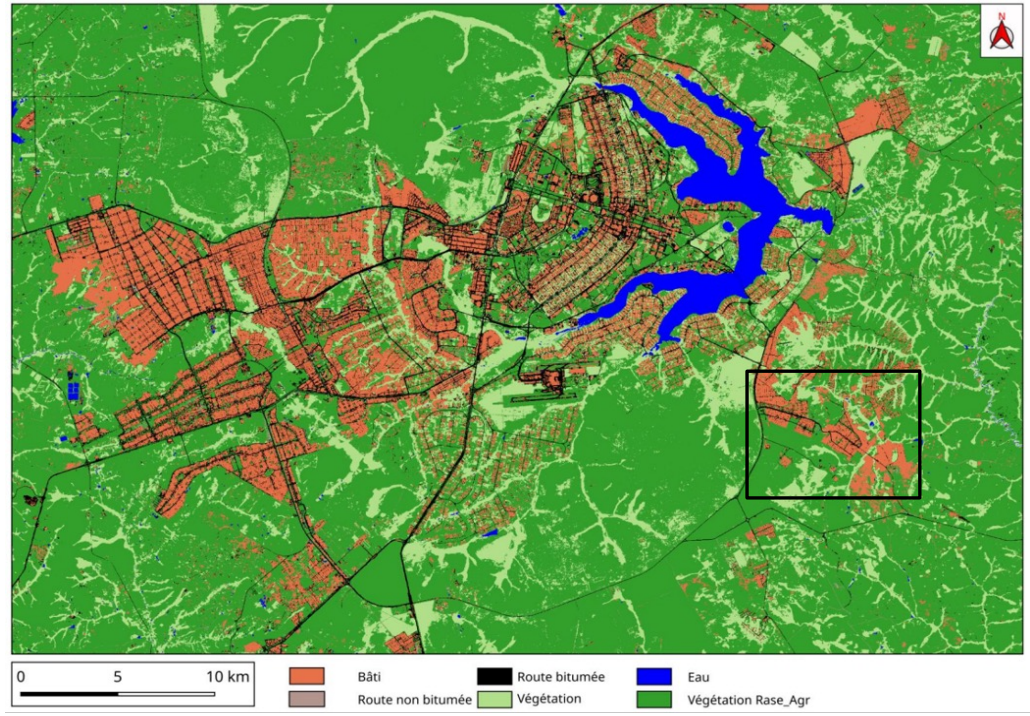


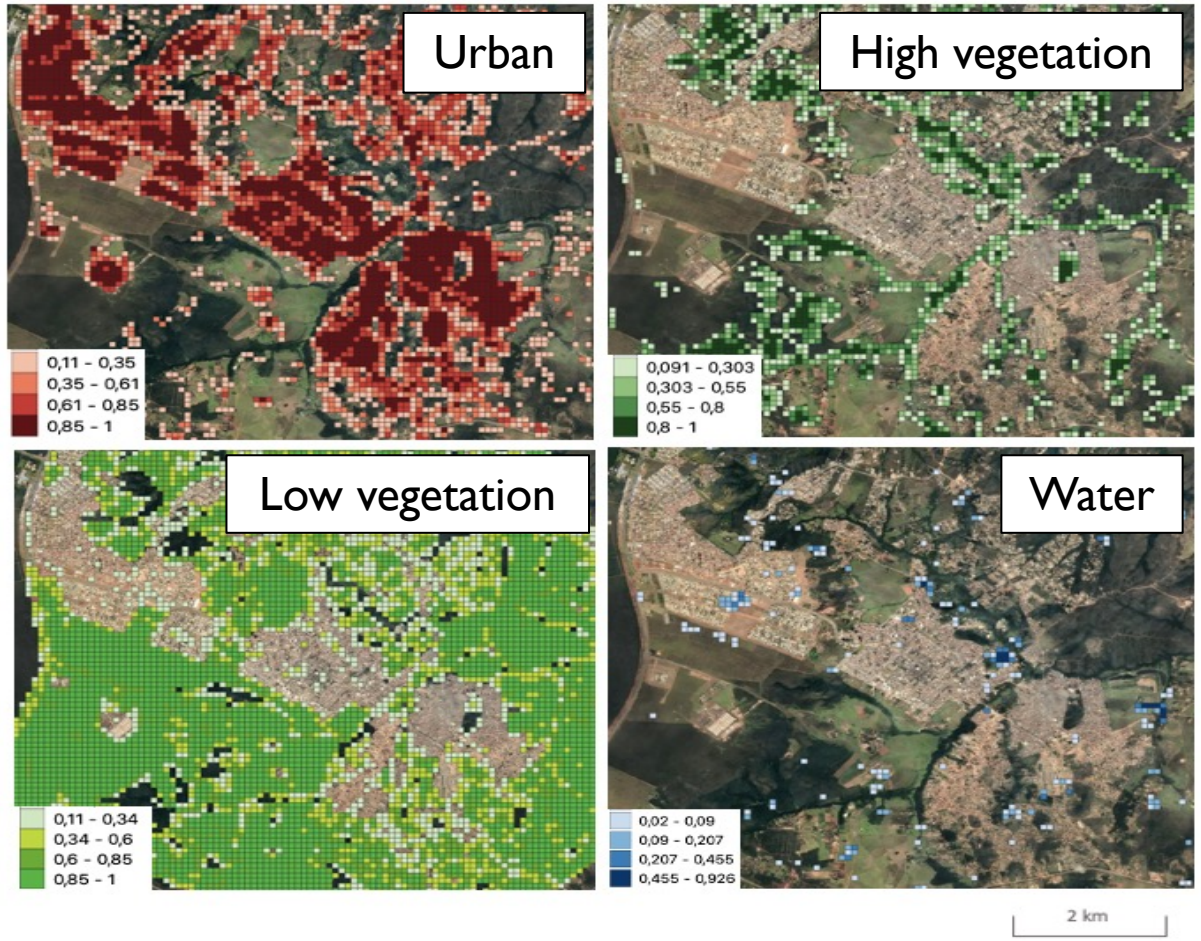
Spectral indexes over Sao Sebastiao (Brasilia) using Sentinel 2 (10 m)

Characterizing urban landscapes using remote sensing data

Earth observation data can be used to produce **environmental variables** on urban areas

Landcover classification over Brasilia using Sentinel 2 timeseries (10 m)

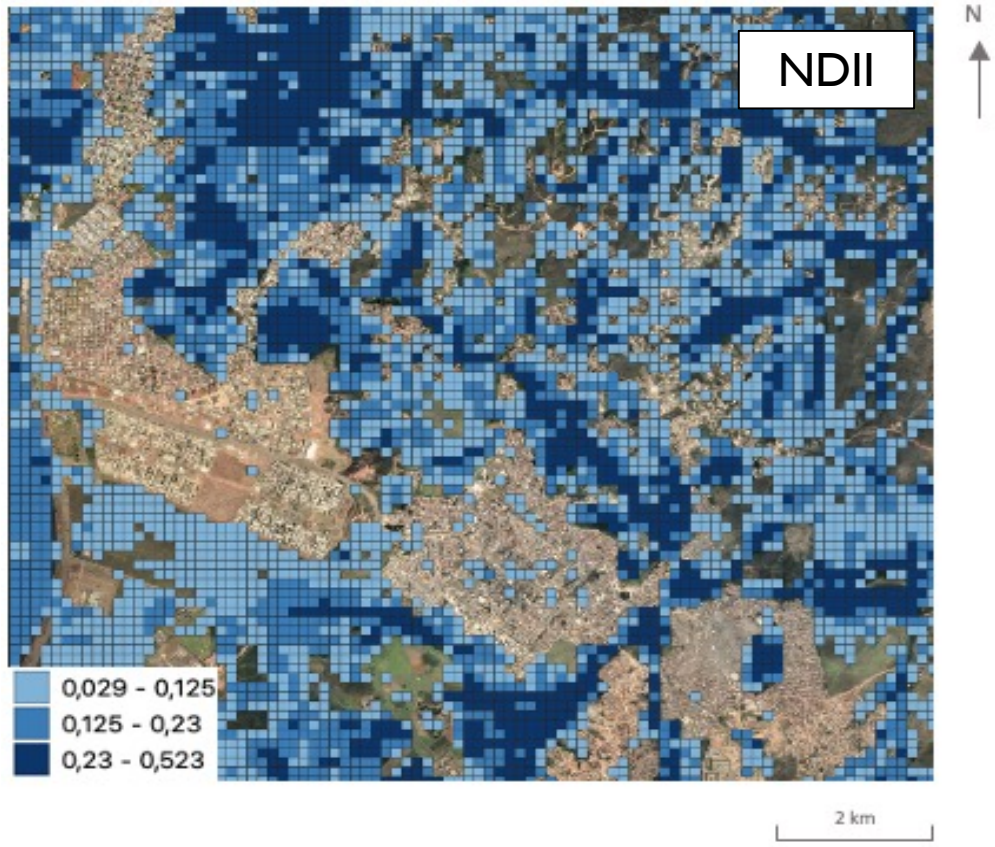


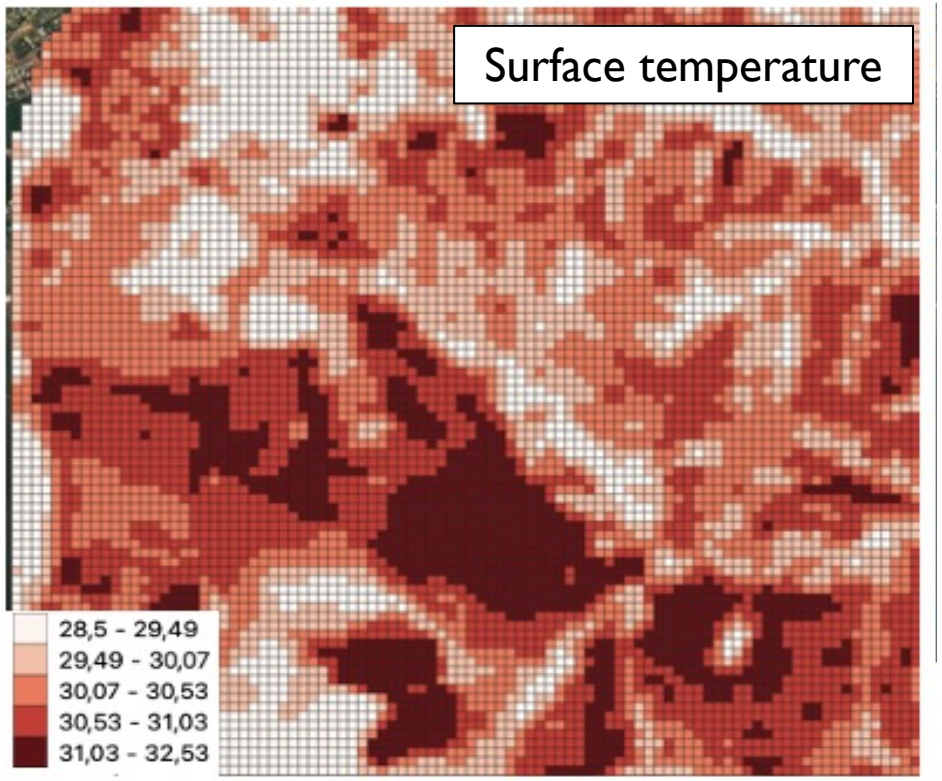


Proportion of each class over a grid cell of 100 x100 m for Sao Sebastiao

Characterizing urban landscapes using remote sensing data

Earth observation data can be used to produce **climatic variables** on urban areas



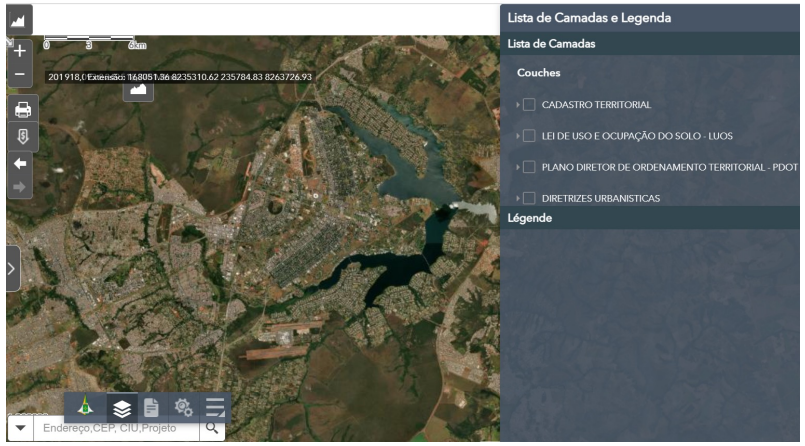


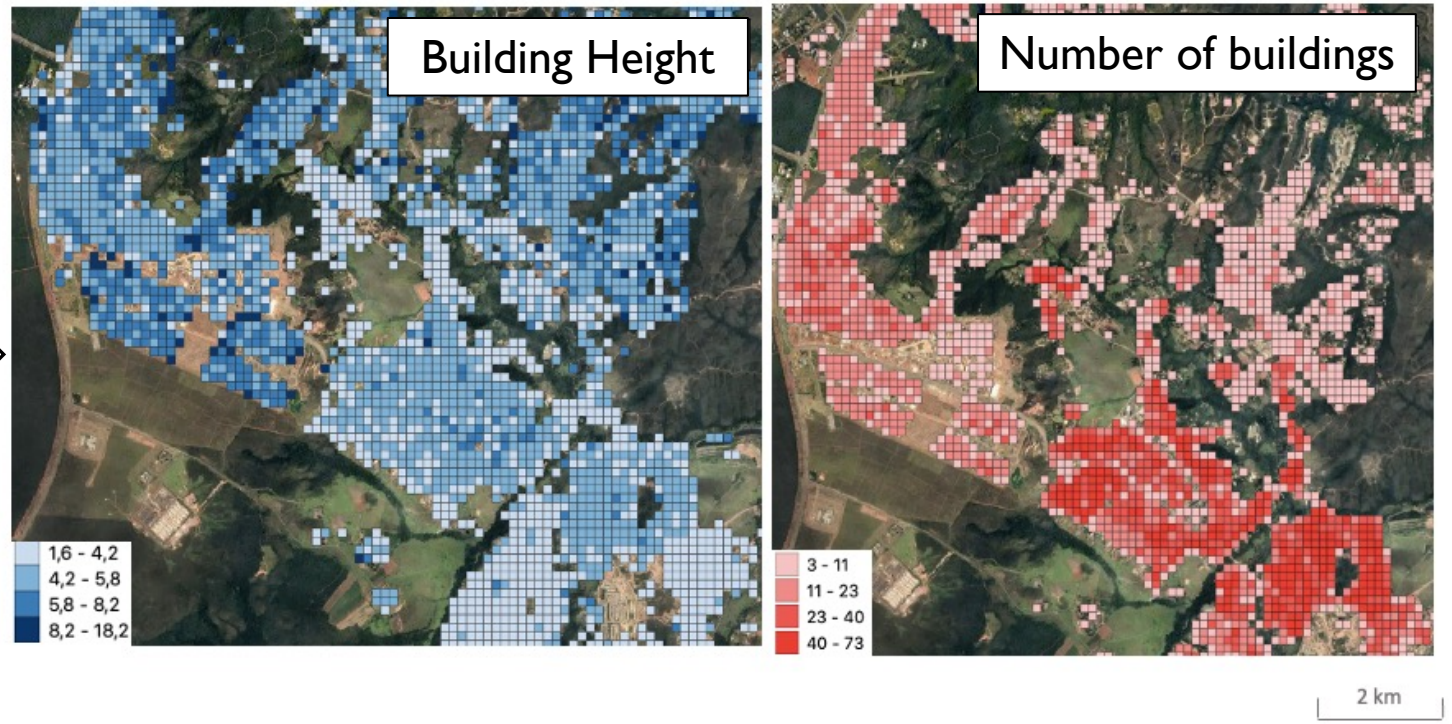
Soil humidity index from Sentinel 2 (10 m) and **Surface temperature** from Landsat 8 (100m) over a grid cell of 100 x100 m for Sao Sebastiao

Characterizing urban landscapes using remote sensing data

Descriptors of urban areas can also come from **geodatabases**

SEDUH database and **Geoportal**



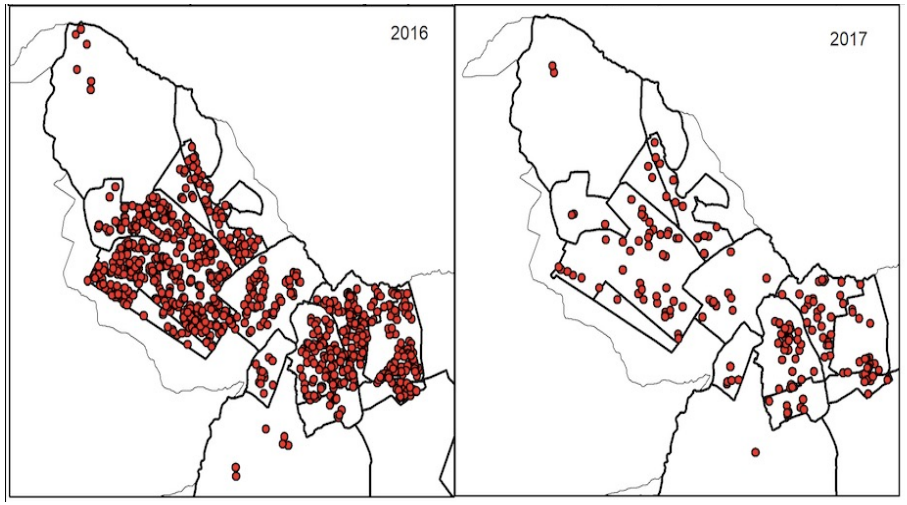


https://www.geoportal.seduh.df.gov.br/geoportal/

Building height and number of buildings
over a grid cell of 100 x100 m for Sao Sebastiao

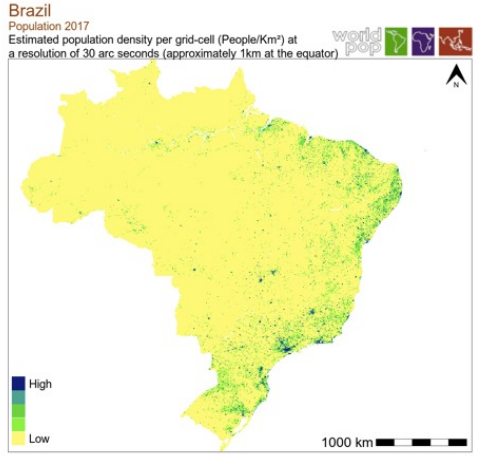
Remote sensing, Urban factors and Dengue cases

Determination of **dengue cases clusters** for 2016-2017 in Sao Sebastiao using SATSCAN, to model the space and time distribution of cases



https://portalsinan.saude.gov.br

SINAN database



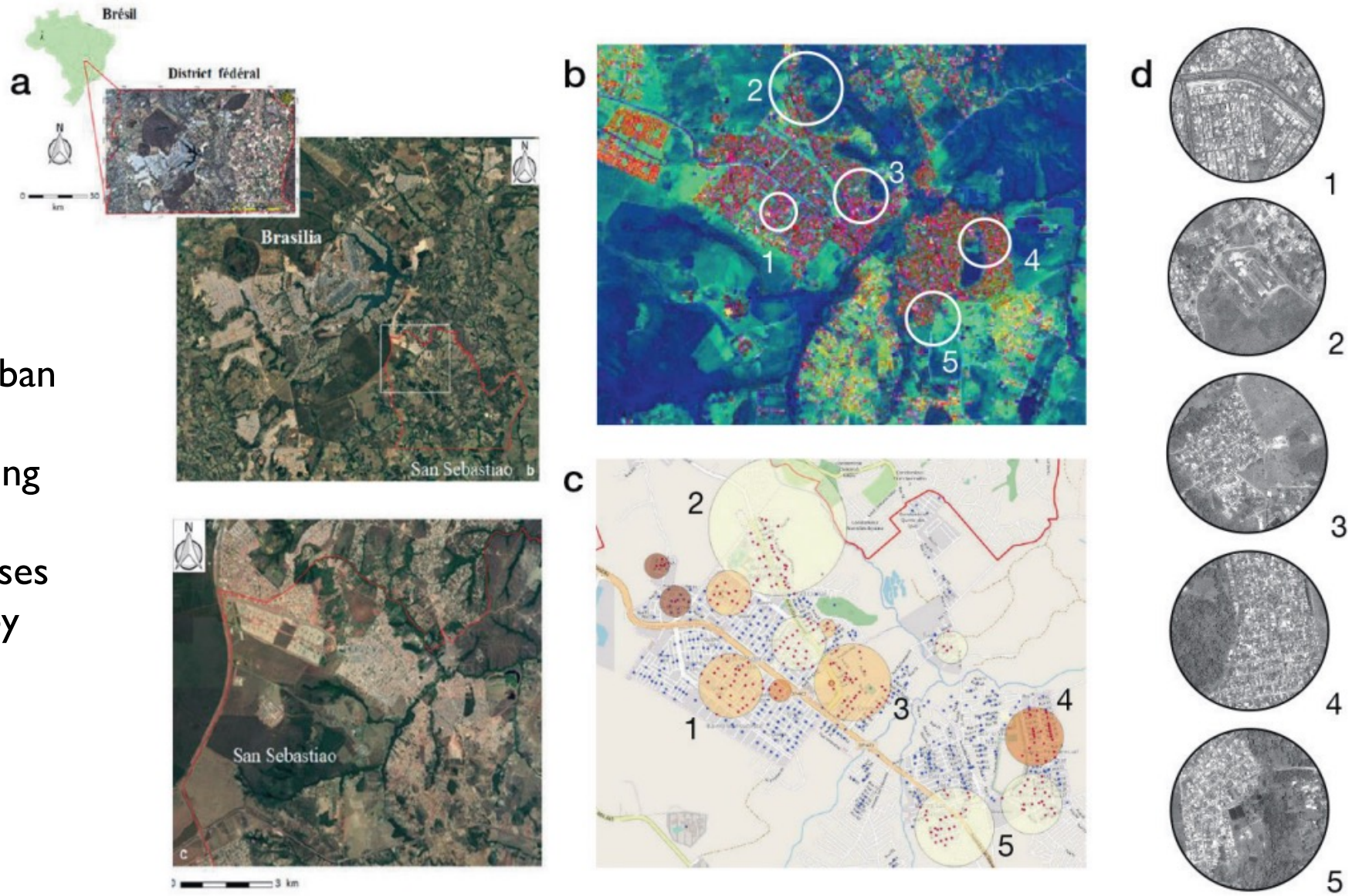
Worldpop

SaTScan™
Software for the spatial, temporal, and space-time scan statistics

The distribution of cases is homogeneous but the intensity of clusters is heterogeneous

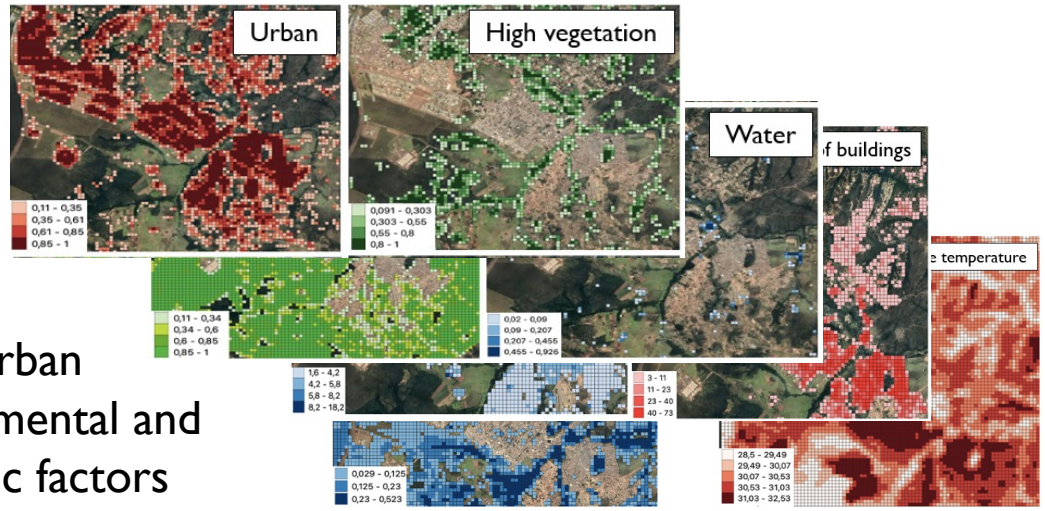
Remote sensing, Urban factors and Dengue cases

Relationship between urban units delineated from textural information using FOTOTEX and the ditribution of dengue cases in clusters produced by SATSCAN



Remote sensing, Urban factors and Dengue cases

Statistical analysis of the **correlations** between previous variables and the distribution of cases in space and time

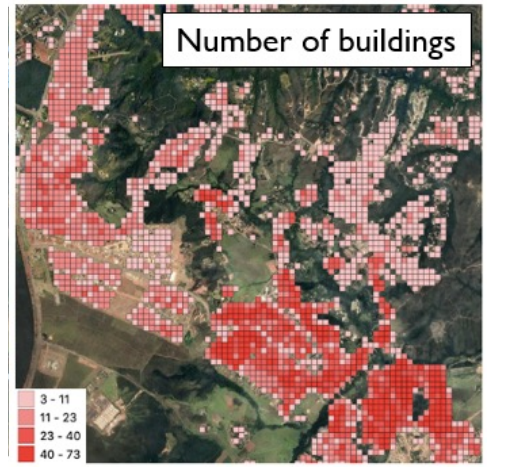


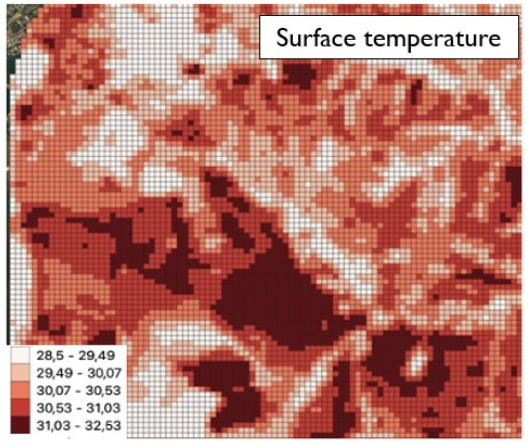
Urban environmental and climatic factors

Model of dengue cases for 2016-2017

Multivariate Statistical Analysis

GLM





Significant and positive correlations between urban factors and dengue clusters

Remote sensing, Urban factors and Dengue vectors

PhD - **Remote sensing analysis of the relationship between urban landscapes and the risk of exposure to *Aedes* mosquitoes, vectors of arboviroses**

Claire Teillet
Directors : Rodolphe Devillers & Emmanuel Roux

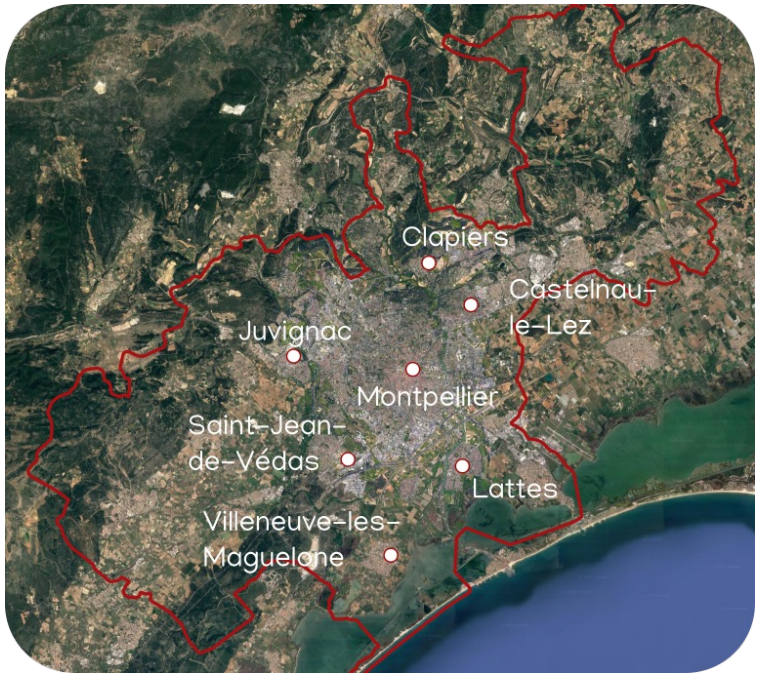
Objective :

Develop an approach to **spatialize the risk of exposure to *Aedes*** mosquitoes that makes the best use of **satellite data** and available data (entomological, epidemiological, etc.) in order to make it **reproducible, generic and adapted** to the needs of health actors.

Link with the health and urban axis of PROGYSAT

Cayenne, French Guiana

Montpellier , Occitanie



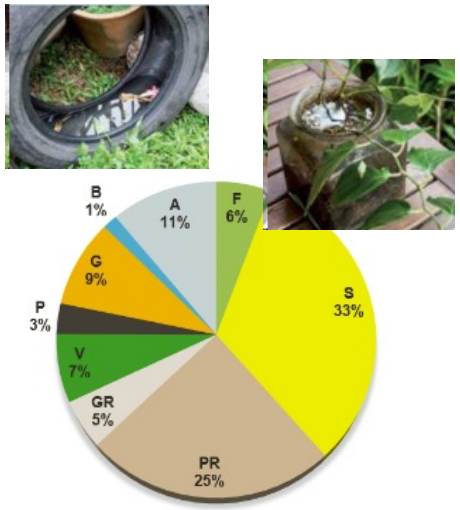
Contrasted study sites in terms of epidemiologic and entomologic situations and environmental / climatic contexts

Remote sensing, Urban factors and Dengue vectors

Focus on the use of urban variables from **remote sensing** to estimate :
the **number of potential breeding sites** and the **density of *Aedes* mosquitoes**

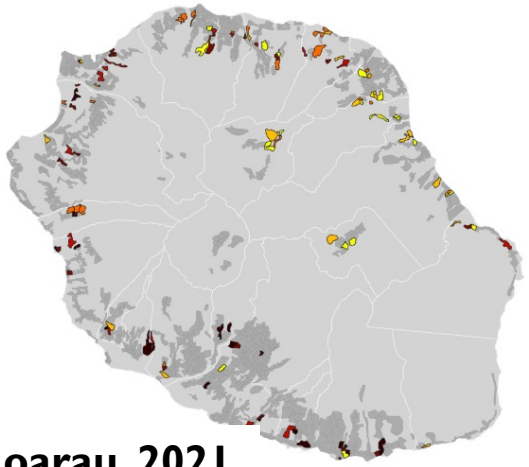
Entomological data as input for the model

Database of number and types of breeding sites was collected by the ARS on 10% of the urban territory of Reunion Island



Differents types of breeding sites

Number of breeding sites colleted



Hoarau, 2021

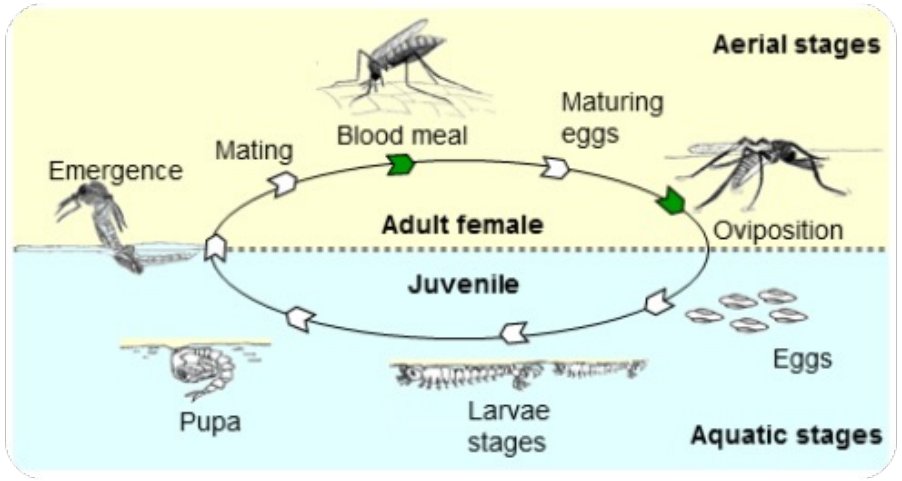
INPUT

"Mechanistic" differential equation model (Tran et al., 2013)

Based on knowledge of the life cycle of the mosquito

ARBOCARTO

https://www.arbocarto.fr/



Remote sensing, Urban factors and Modelling of potential breeding sites

Focus on the use of urban variables from **remote sensing** to estimate :
the **number of potential breeding sites**

Statistic model developed to predict the number and types of breeding sites over Reunion Island (Hoarau, 2021)

Explicative variables

Environmental variables

- Spectrals indices (vegetation, brightness, humidity)
- Textural indices from FOTOTEX

Topo-climatic variables

- Altitude
- Annual average temperature
- Rainfall cumul

Dependant variable

Entomologic data

- Number and types of gites from field

Generalized linear model

Spatialized prediction of the number and type of potential breeding sites

Remote sensing, Urban factors and Dengue vectors

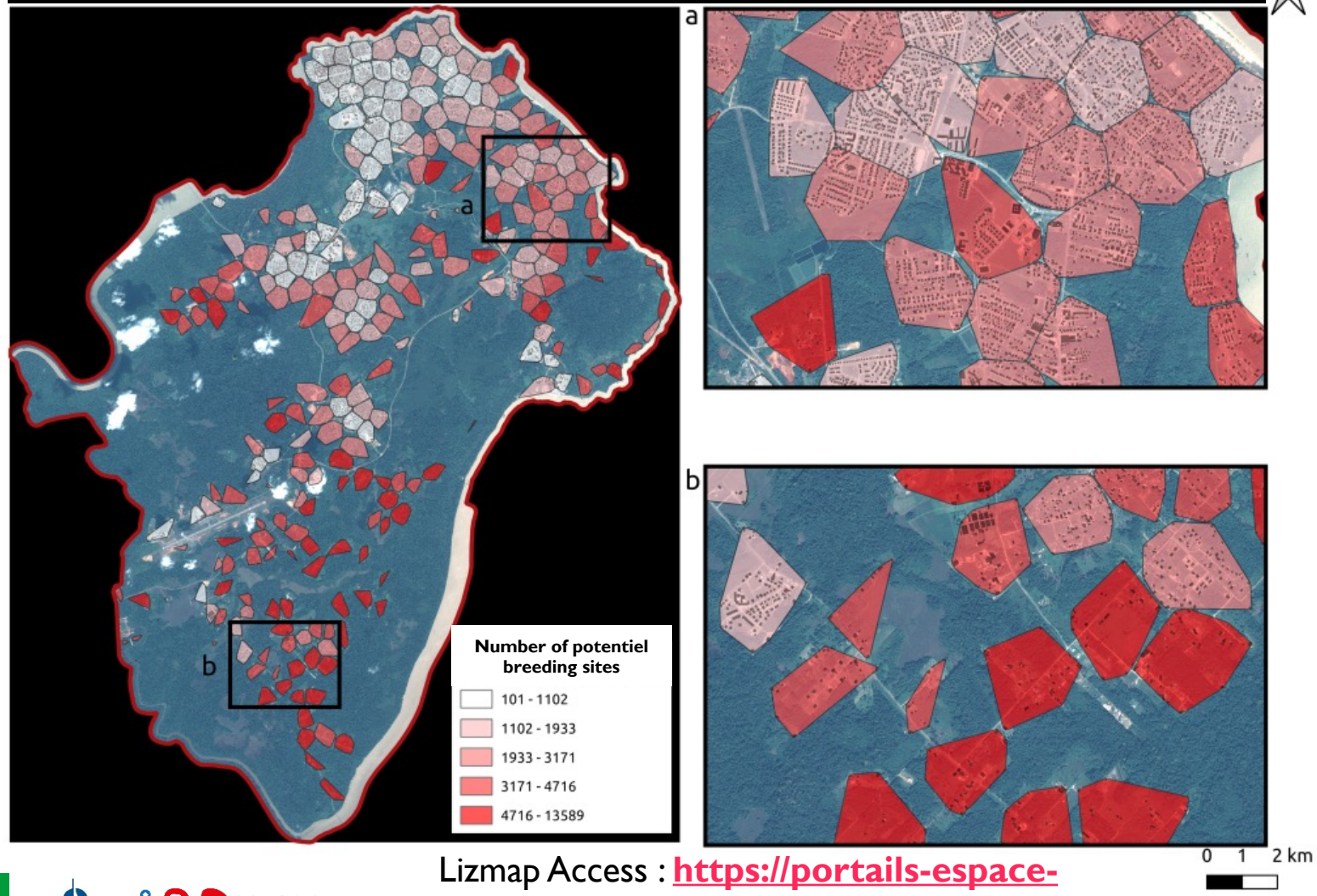
Focus on the use of urban variables from **remote sensing** to estimate the **number of potential breeding sites**

Exploratory approach to test a model developed in Reunion Island on Cayenne (French Guiana)

→ Requires adaptations and improvements

Incorporating other urban variables from remote sensing (vegetation height, buildings height…) and improving spatial clustering

First result of the statistic model applied to Cayenne



Lizmap Access : https://portails-espace-dev.teledetection.fr/

Remote sensing, Urban factors: towards human exposure to mosquitoes

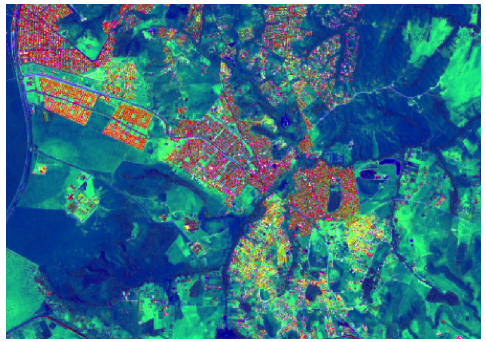
Combining variables from remote sensing, with data from **seroprevalence** studies can help assess human exposure to dengue virus and possibly to mosquitoes, and validate model outputs describing the interactions between humans and vectors in urban areas

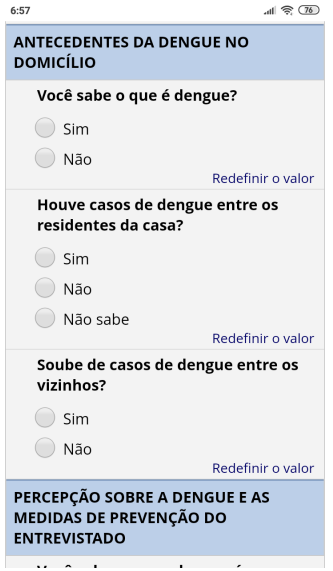
An example from a seroprevalence campaign in the DF, Brazil (approx. 2200 samples)

Determination of exposure to arboviroses (dengue, ZikaV, ChikV) (IgG, IgM)

Perspective : exposure to mosquito bites (coll. MIVEGEC)

Serological survey + Knowledge, attitude and practice questionnaire





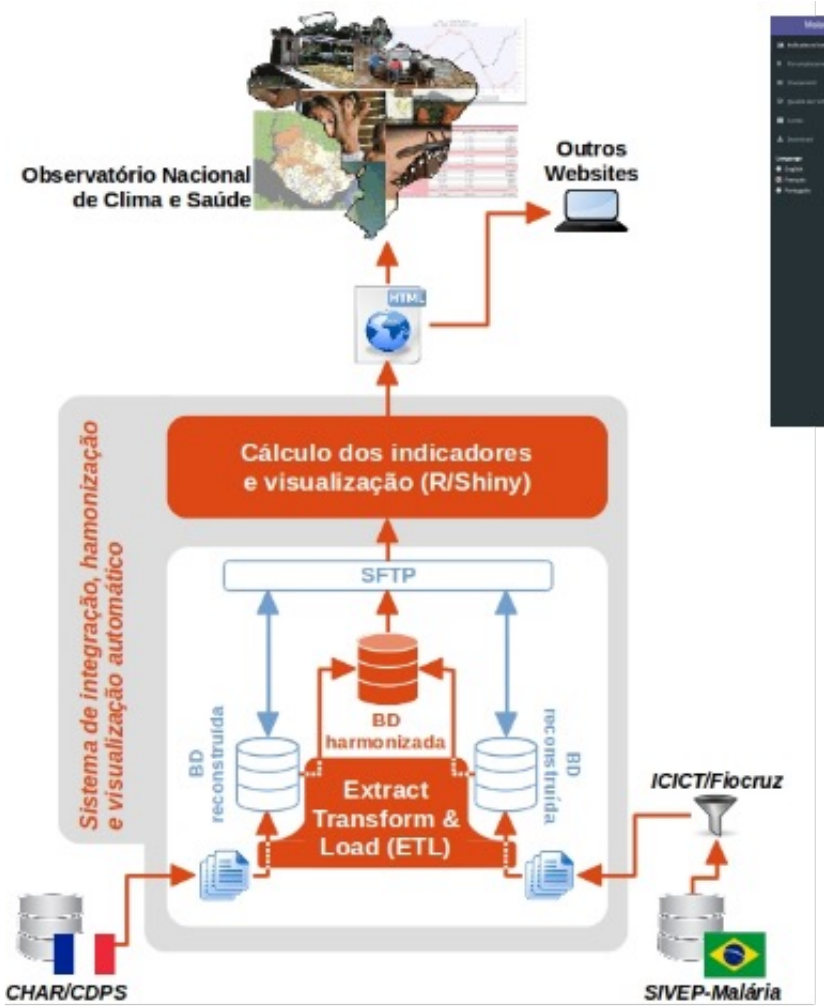
Projection of the seroprevalence data on the 100x100m grid of environmental variables to run statistical analysis

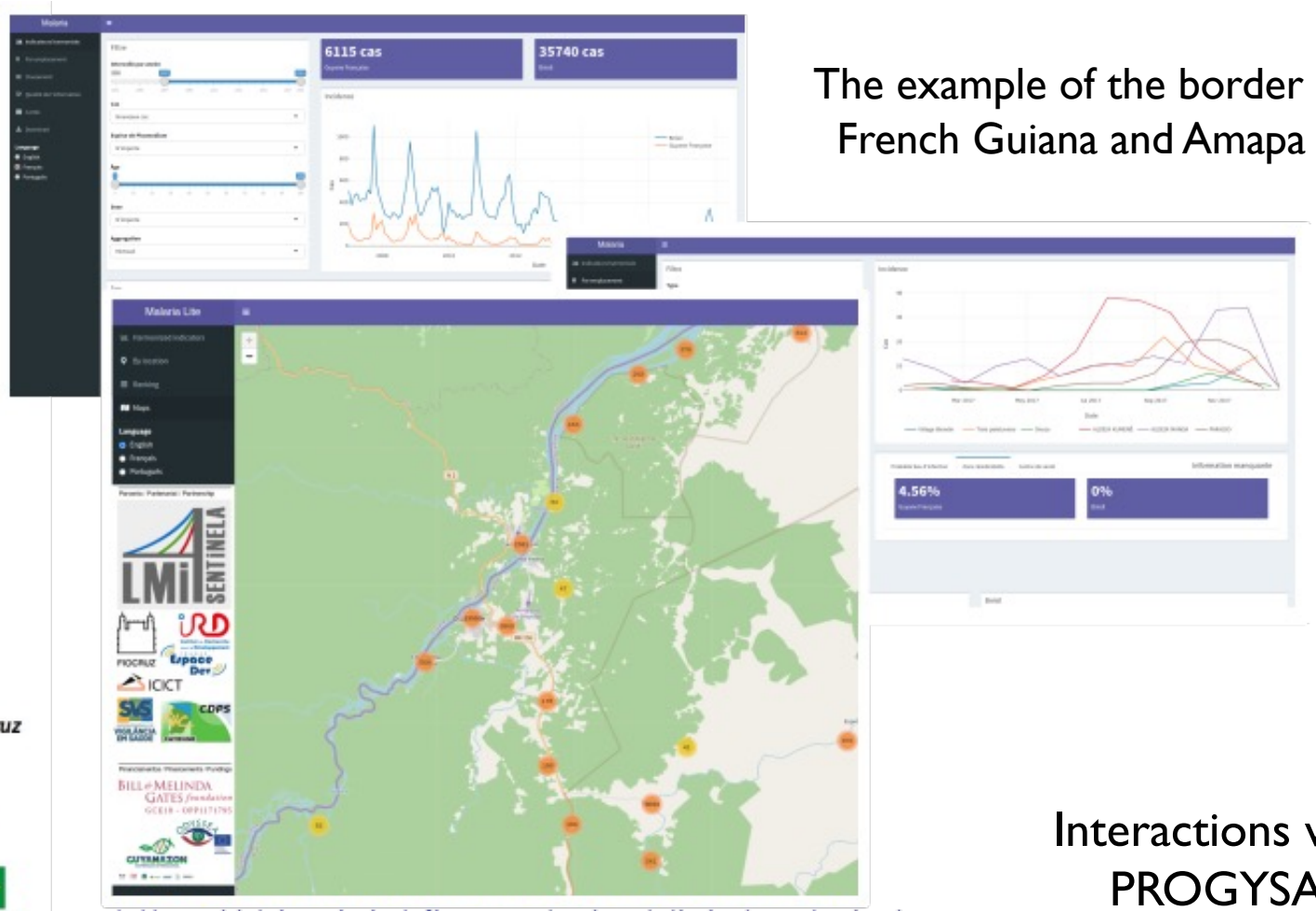
Operational activities in Remote sensing and spatial modelling

Towards the development of monitoring and early warning systems

Remote sensing and modelling: towards monitoring and early warning systems

System of **Harmonization and visualization of epidemiological data** for **health monitoring** in cross-border context





https://shiny.icict.fiocruz.br/publicirdmalaria/

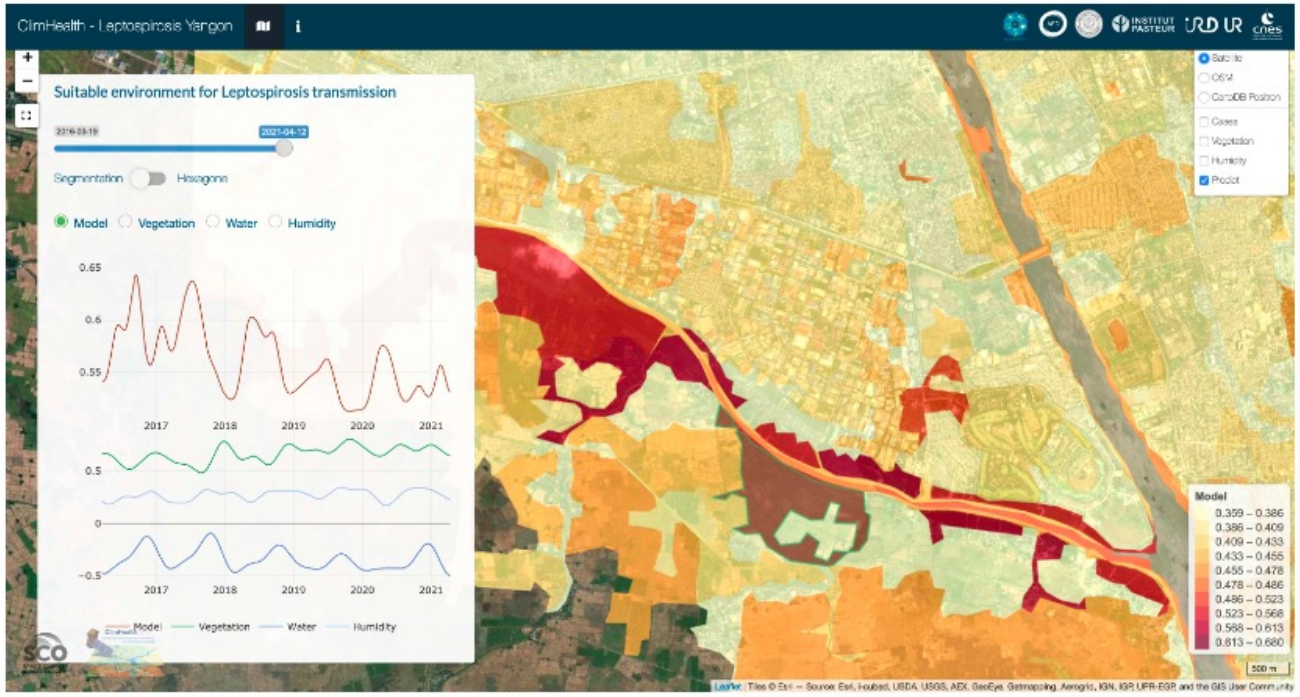
The example of the border between French Guiana and Amapa (Brazil)

Interactions with PROGYSAT « Health »

Saldanha et al., 2020

Remote sensing and modelling: towards monitoring and early warning systems

Funded by the SCO (Space Climate Observatory, CNES)

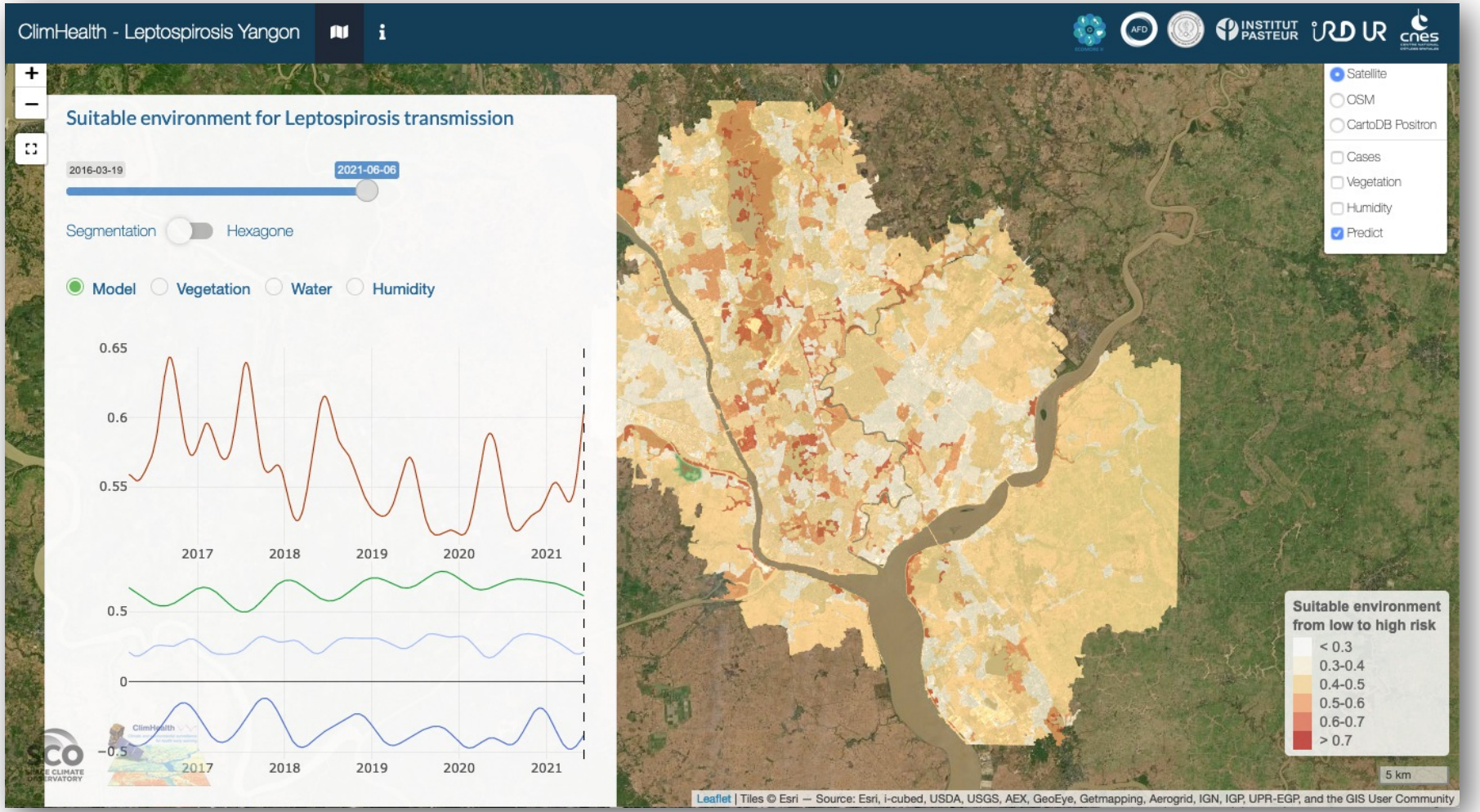


NDVI, MNDWI and NDWI timeseries from Sentinel 2

Global model for predicting environments favorable to leptospirosis based on the 3 indices.

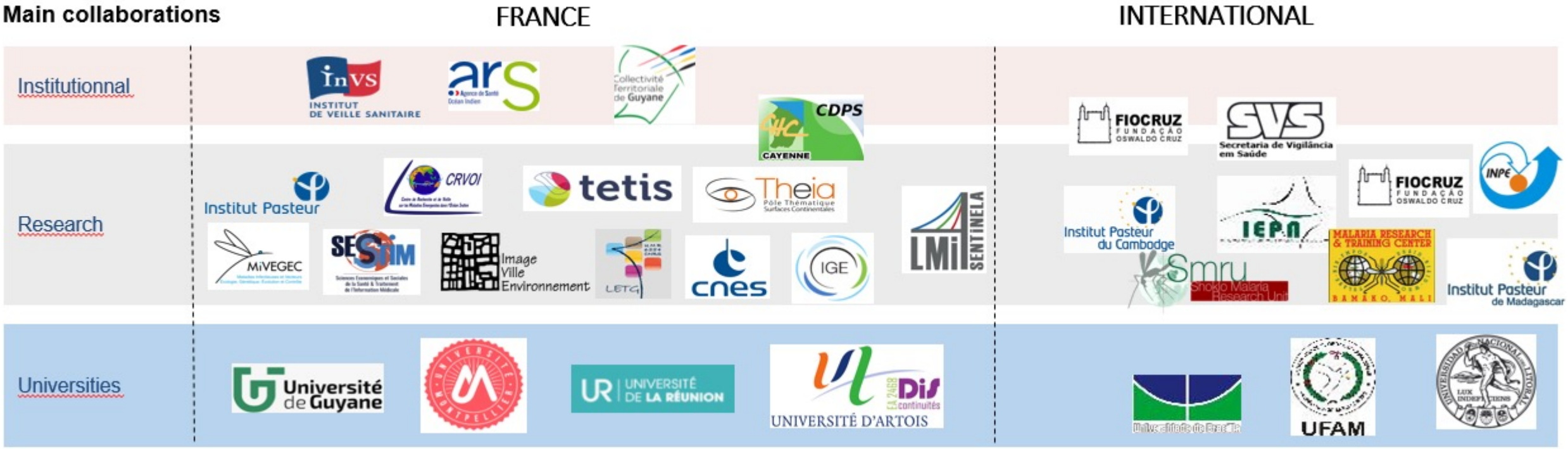
Remote sensing and modelling: towards monitoring and early warning systems

Integration of climate and environmental information from satellites into **health surveillance systems** to develop **early warning and guide disease control** (R-shiny interface)



https://leptoyangon.geohealthresearch.org/

Research and operational activities in collaboration with a network of partners



Research and operational activities in collaboration with a network of partners

Animation Régionale PAYS DU SUD

Theia GEODEV

Strengthen interactions between thematic axis of PROGYSAT, local researchers and public actors

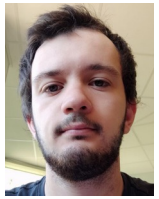
seas GUYANE

Thank you
Dankjewel
Obrigado
Merci

















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Collectivité Territoriale de Guyane
l'Europe s'engage en Guyane avec le FEDER et le FSE
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